

INTRODUCTION TO HEATSINK DESIGN



A heat sink is normally required when using high power amplifiers. Evaluation of heat sink requirements is easy and can lead to cost savings or increased reliability.

Utilising a simple analog to an electric circuit, the "Ohm's law" of this thermal model states that the temperature rise across a thermal resistance is equal to that thermal resistance times the power dissipated

$$\Delta T = \Theta P$$

Where: T is the temperature rise

Θ is the thermal resistance in $^{\circ}\text{C}/\text{W}$

P is the amplifier's power dissipation in watts

The power dissipated in the power amplifier depends on the supply voltage, electrical load, and signal conditions. For non-reactive loads the maximum dissipation is:

$$P_{\text{MAX}} = \frac{V_s}{4R_{\text{LOAD}}}$$

Where: V_s is the supply voltage referred to load ground (one side, not the sum of $+V - V_s$) & R_{LOAD} is the load resistance)

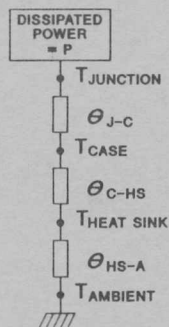
The allowable temperature rise is dependent on the ambient temperature conditions and the maximum allowable junction temperature, T_{JMAX} , as specified by the power amp manufacturer. It normally ranges from 150°C to 200°C . It should be recognised that, as with any electronic component, improved reliability can be achieved by choosing a more conservative operating point.

Once the power dissipation and temperature rise are determined, the thermal resistance, Θ , may be calculated:

$$\Theta_{\text{J-A}} = \frac{\Delta T}{P}$$

$\Theta_{\text{J-A}}$ is the total thermal resistance from junction to ambient and is comprised of three major parts

The thermal resistance from junction to case, $\Theta_{\text{J-C}}$, is specified by the power amp manufacturer



2. The thermal resistance from the power amp case to the heat sink, $\Theta_{\text{C-HS}}$, depends on heat sink mounting surface flatness. Heat sink compound reduces $\Theta_{\text{C-HS}}$ in the presence of small surface imperfections but it is not a substitute for good heat sink workmanship. Typical values for a T Θ -3 type package range from $0.1^{\circ}\text{C}/\text{W}$ to $0.5^{\circ}\text{C}/\text{W}$. Power amps or transistors with electrically hot cases usually require insulating hardware which adds as much as $1.0^{\circ}\text{C}/\text{W}$ to $\Theta_{\text{C-HS}}$

3. TMShe thermal resistance from heat sink to ambient, $\Theta_{\text{HS-A}}$, is determined by the heat sink and environmental factors such as air flow or convection currents.

The total thermal resistance, $\Theta_{\text{J-A}}$, is the sum of these three thermal resistances. The required Θ for the heat sink ($\Theta_{\text{HS-A}}$) is equal to the total thermal resistance less the $\Theta_{\text{J-C}}$ and $\Theta_{\text{C-HS}}$.

$$\Theta_{\text{HS-A}} = \Theta_{\text{J-A}} - \Theta_{\text{J-C}} - \Theta_{\text{C-HS}}$$

EXAMPLE:

$$\begin{aligned} T_{\text{J}} &= 180^{\circ}\text{C} \\ T_{\text{A}} &= 60^{\circ}\text{C} \text{ (maximum ambient temperature)} \\ P &= 25\text{W} \text{ (depends on } +V_s \text{, load etc.)} \\ \Theta_{\text{J-A}} &= (180 - 60) / 25 = 4.8^{\circ}\text{C}/\text{W} \text{ (this is not the required heat sink } \Theta) \\ \Theta_{\text{J-C}} &= 2.2^{\circ}\text{C}/\text{W} \text{ (from power amp specification)} \\ \Theta_{\text{C-HS}} &= 0.2^{\circ}\text{C}/\text{W} \text{ (good surface with thermal compound)} \\ \Theta_{\text{HS-A}} &= 4.8 - 2.2 - 0.2 = 2.4^{\circ}\text{C}/\text{W} \end{aligned}$$

The required heat sink must have a thermal resistance of $2.4^{\circ}\text{C}/\text{W}$ (or lower) to adequately cool the power amp. It is conceivable that this calculation might result in a negative number for $\Theta_{\text{HS-A}}$. This means that a perfect or infinite sink is not good enough. An alternative approach must be selected.

Once the required Θ for a heat sink is determined, it may be compared to published data for Assman heat sinks.

It is easy to verify thermal performance by measuring the power amp's actual case temperature under operating conditions. T_{CASE} is measured by placing a thermocouple under one of the mounting screws of the power amp (or at a place on the case specifically indicated by the manufacturer for such a measurement). The junction temperature can then be calculated:

$$T_{\text{J}} = P\Theta_{\text{J-C}} + T_{\text{CASE}}$$

$$\begin{aligned} \text{e.g.:} \\ P &= 25\text{W} \text{ (dependent on application)} \\ \Theta_{\text{J-C}} &= 2.2^{\circ}\text{C}/\text{W} \text{ (from power amp specification)} \\ T_{\text{CASE}} &= 95^{\circ}\text{C} \text{ (as measured with thermocouple)} \\ T_{\text{J}} &= (25)(2.2) + 95 = 150^{\circ}\text{C} \text{ (safe)} \end{aligned}$$

This is the most direct means of assuring that the junction temperature is maintained within safe bounds. This approach still requires knowledge of the power amplifier dissipation. For AC signals, reactive loads, motors or widely varying signal conditions this may be difficult to calculate but further information is available.

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